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Marlene H. Dortch
Federal Communications Commission
445 12th Street, SW
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Subject:
WT Docket No. 16-239
RM-11831

Dear Ms Dortch,

This letter addresses issues of spectrum allocation relevant to narrowband and wideband HF amateur radio emissions that create compatibility challenges, and to issues of transparency and documentation of digital modes of emissions. I respectfully ask the commission to reject WT Docket No. 16-239 and to adopt RM-11831. Findings on key technical issues are included in this letter showing why this is needed due to significant incompatibility issues between wideband digital emissions and narrowband emissions. Findings on documentation and transparency are also included.

In a previous letter, it was found that spread spectrum techniques combined with auto-notch filters have been introduced into HF wideband digital modems.[1] This has strong implications for compatibility with narrowband signals. In this letter detailed technical analysis is provided on PACTOR-4 showing the nature of the spread spectrum used in that modem. It is also found that VARA public domain technical information is very limited and adequate specification documentation is not available. But also, even with the limited information available, it is shown that VARA almost certainly uses spread spectrum techniques due to very large bandwidth to information ratios for some emissions. While these issues of compliance with existing Part 97 regulations on spread spectrum should be clarified, these issues amplify the problems of compatibility of wideband and narrowband emissions in the same band segments.

[1] ttps://ecfsapi.fcc.gov/file/11170346002261/FCC letter RM-11831 WT Docket No. 16-239%20 Nov 16 2019 NRS.pdf

Spread spectrum definition

A variety of definitions of spread spectrum (SS) can be found in the technical literature and in radio regulations. One of the best may be found in FCC RM-11325: "Spread spectrum techniques are emissions that use bandwidth-expansion modulation techniques to intentionally spread the information transmitted over a wide bandwidth." This definition goes directly to the core characteristics of spread spectrum techniques with concise language and addresses: 1) direct sequence spread spectrum (DSSS); 2) frequency hop spread spectrum (fast and slow); 3) chirp spread spectrum; 4) very low-rate channel coding spread spectrum; 5) OFDM or frequency domain spread spectrum techniques; 6) hybrid combinations of these techniques; and 7) new or unknown techniques at this time that may emerge from innovation. This definition simply says that if the transmitted bandwidth is wide for given information then some form of processing is being used that is "spread spectrum" without attempting to define how the spreading of the spectrum is achieved.

But what is "wide bandwidth"? This can only mean relative to the information rate and not some arbitrary absolute bandwidth. For example, CHIP64 [2] uses only a 300 baud chip or spreading rate and is less than 500 Hz in transmitted bandwidth, but it is accepted and designed as SS. The creator of CHIP64 is very clear on this. Furthermore CHIP64 satisfies the FCC RM-11325 definition. CHIP64 uses spreading rates of 64x or 128x, and supports information bit rates of 37.5 bits/sec and 21.09 bits/sec respectively, but in a transmission bandwidth of about 400 to 500 Hz (300 baud symbols with TX filtering). Hence the ratio of transmission Bandwidth To Information rate (BTI is ~ 10x and ~ 20x respectively. This ratio is much greater than 1x, but when does this ratio mean SS is used? If the ratio exceeds about 5x to 10x, then SS techniques are almost certainly being used, and the next few paragraphs give a discussion on this.

For PACTOR-4, sending level 4 using a spreading factor of about 8x. It is the fastest mode which clearly uses SS techniques based on the description. Sending level 4 transmits about 307 information bits per second using a bandwidth of 2400 Hz, so the BTI is 7.8x. Sending level 3 transmits about 153 information bits/sec, so the BTI is 15.6x, and the ratios are 26x and 45x for sending levels 2 and 1. Sending level 5 transmits about 440 information bits per second, so the BTI is about 5.4x. Sending level 5 does not use SS based on the technical description. It does use 1/3 rate convolutional coding and binary modulation with BPSK.

The use of binary PSK modulation (lowest possible number of levels for digital modulation and only 1 bit/symbol) combined with a strong low-rate convolutional channel code of 1/3 represents a good benchmark to differentiate between spread and non-spread signals. Once channel coding rates go below about 1/3 assuming binary modulation, the behavior of the coding becomes similar (asymptotes) to concatenating DSSS with 1/2 or 1/3 rate coding at the same overall rate. There exists an area of coding focused on very low rate channel coding where the spreading is achieved in the coding function itself.[3] [4] Hence it must be understood that the use of very low coding rates is considered SS even though

[2] http://antoninoporcino.xoom.it/Chip64/Chip64_description.pdf
[3] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.157.1156&rep=rep1&type=pdf
[4] https://ewh.ieee.org/r6/lac/csspsvts/briefings/Coding_Part3.pdf

no direct sequence, frequency hopping or chirp spreading is involved.   Together, binary modulation and 1/3 rate channel coding suggest a BTI of 3x between spread and non-spread spectrum systems. However, any system will include a number of overheads such as: 1) channel bandwidth expansion in TX filtering; 2) channel estimation symbols; 3) packet synchronization symbols; 4) transmission start/stop guard times; and 5) ARQ acknowledgements. Allowing for these physical layer overheads, an additional ratio approaching 2x to 3x is possible. Overall a BTI of 5x to 10x appears appropriate to determine SS usage.

A BTI of 3x (1/3 bit/sec/Hz), not considering physical layer overheads, is directly driven by fundamental information theoretic issues. Shannon's capacity limit is one of the best known theorems in communications.

$C=B*Log_2(1+S/N)$

C: Channel capacity(bps)
B: Bandwidth(Hz)
S: Total Signal Power over the Bandwidth
N: Total Noise Power over the Bandwidth

For a fixed transmission power level on an AWGN channel where the bandwidth is not limited, the capacity limit has a gap of about 2.3 dB at 1 bit/sec/Hz, 1.14 dB at 1/2 bit/sec/Hz, 0.74 dB at 1/3 bit/sec/Hz, and 0.36 dB at 1/6 bit/sec/Hz (spreading the spectrum of the signal with fixed power out as far as possible which lowers SNR due to increasing noise with bandwidth optimizes performance against AWGN noise). Below 1/3 rate channel coding with binary modulation, performance against noise improves very slowly with further reductions in channel coding rates, and the gap is already at only 0.74 dB for ideal codes at 1/3 rate.   This suggests that when the BTI is greater than 3X, not considering overhead (5X to 10X with physical layer overhead), something else is involved such as robustness to interference and possibly the ability to overpower narrowband transmissions.

What happens with this test for popular narrowband amateur radio modulations like PSK31, Clover, JT65, JT9, FT8 and legacy RTTY? How about for wideband HF modems besides PACTOR-4 like PACTOR-3 and VARA? An analysis shows that all of the narrowband modes are determined NOT to be SS based on this test with the exception of JT65A which has largely been replaced by FT8 and JT9 on HF bands. JT65 was originally driven literally by moon-bounce signal design and every 0.1 dB was important while information bit rate was not very important, so very low rate coding was used for it. There are no suggestions of SS processing in the descriptions of the narrowband technologies PSK31, Clover, JT65, JT9, FT-8 and legacy RTTY, but they also pass the BTI test of < 5x to <10x (except for JT65A). JT9 may fail this test marginally, but see the further discussion on JT9.

PSK31 transmits data at 31.25 bits/sec in a bandwidth of only 60 Hz.[5] It either uses uncoded binary BPSK or ½ rate coded QPSK, both support 31.25 bits/sec (ignoring coding tail bits). Transmissions include preambles and postambles, so efficiency varies, but even assuming the time in preamble and postamble

[5] http://www.arrl.org/psk31-spec

combined equals the time in data transmission, the BTI is about 4x. The observation that users can dwell on a channel indefinitely without sending useful data should not be counted in such analysis. Hence PSK31 is not SS.

Clover uses 6 transmission modes with information bit rates of 62.5, 125, 250, 375, 500 & 750 bits/sec in a 500 Hz channel. The lowest rate mode has a BTI of 8x and the second level mode has a BTI of 4x. The lowest rate mode is between the 5x to 10x BTI test, but that is the worst case mode. It is not SS.

JT65A sends 72 bits of user information in 46.8 seconds using 177.6 Hz of bandwidth.[6] The BTI is about 115x! Even though the BW is fairly small, this technically qualifies as SS due to the extremely low user bit rate. This appears though to be in declining usage on HF bands with newer modes FT8 and JT9 replacing it. The long transmission is one problem for this mode on HF, as well as the wide bandwidth compared to FT8 and JT9, and the need to synchronize transmission/reception frame times independently of the modem itself. JT65A does have a few dB advantage in sensitivity compared to FT8, of course. The very high BTI of JT65A is substantially driven by very large overhead for synchronization and the usage of high order 65-FSK, but it also uses < 1/5 rate channel coding.

JT9 uses a very narrowband of only 15 to 20 Hz. It transmits 72 bit messages in about 50 seconds. Hence the BTI is about 10x to 13x which is borderline SS. However, the extremely narrow bandwidth is an efficient use of spectrum in the HF bands although simple exchanges may take 4 to 6 minutes. Since the bandwidth is very narrow and the goal is weak signal communications, a higher BTI is probably not a problem.

FT8 sends 77 bits of user information in 12.5 seconds with a bandwidth of only 50 Hz. The BTI is 8.1x. This ratio is between the 5x to 10x BTI test for SS and using only 50 Hz of spectrum for a QSO, it is highly efficient. FT8 is now quite popular on HF. It is not SS.

Legacy RTTY uses binary FSK. The most common mode is 170 Hz shift between tones at 45.45 baud. Baud rates of 50, 75 and 100 are also used, and larger frequency shifts may sometimes be used. Due to legacy reasons, shifts of up to 1000 Hz are permitted by Part 97. This permits the usage of legacy transmitter and receiver equipment with substantial frequency drift, but this is rare today, and may be used mostly for demonstrating antique equipment probably during periods of lower activity. The most common modes of RTTY today have BTI's of about 5x to 10x. It is not SS.

Does VARA use spread spectrum?

VARA uses OFDM with 52 tones or carriers with a 37.5 baud rate and a bandwidth of 2.4 KHz [7] It is a complicated and capable modem with 11 modes or adaptive modulation and coding levels. The technical description document is 8 pages long. The channel coding is documented this way:

"Turbo codification is used for the Forward Error Correction with different redundancy
levels to give 11 speed Levels with different Net Data Rates."

[6] https://physics.princeton.edu/pulsar/k1jt/wsjtx-doc/wsjtx-main-2.1.1.html#PROTOCOL_OVERVIEW
[7] https://rosmodem.wordpress.com/

Clearly this does not document the channel coding forward error correction function with no detail provided. There are many other areas of missing detail such as any usage of code puncturing, and the constellation bit mapping functions among others.

VARA 3.0 SPEED LEVELS

Level	Symbol Rate	Carriers	Modulation	Net Data Rate	User Data Rate
1	47	48	FSK	41	33
2	47	48	FSK	82	70
3	94	24	FSK	175	155
4	94	24	FSK	272	243
5	125	3	4PSK	362	325
6	75	8	4PSK	587	530
7	75	12	4PSK	886	802
8	42	48	4PSK	1978	1796
9	42	48	8PSK	2968	2695
10	42	48	16QAM	3473	3149
11	42	48	32QAM	4347	3940
12	42	48	32QAM	5783	5066
13	42	48	32QAM	6920	6030

The net data rate for VARA varies from 6782 bits/sec for level 11 to only 41 bits/sec for level 1 for VARA level 1. All levels of adaptive modulation and coding use a 2.4 KHz bandwidth and all 52 tones or carriers.

Levels 1 to 4 have BTI's of 58.5x, 29.2x, 13.7x, and 8.8x respectively. Hence these levels appear to be SS. How the spectrum is spread is not known based on the limited technical description. It is possible to speculate on several most likely possibilities for the spectrum spreading techniques, but regardless of the exact technique, this qualifies as SS.

It is well known in the art, that OFDM with channel coding, especially low rate channel coding, is resistant to narrowband interference. This motivates using wider channels and then low rate coding to overpower narrowband interference. However, it is also known that adaptive notch filters placed in front of an OFDM receiver processing function will enhance OFDM resistance to narrowband interference and can suppress extremely strong narrowband interferers while maintaining operation of the OFDM link.[8] In this case, a narrowband interferer up to 30 dB stronger than a desired OFDM signal is suppressed and the modem maintains performance. The number of OFDM tones used in this work was 64 similar to the number of 52 tones used in VARA. VARA may or may not include such automatic adaptive notch filters, but this feature is included in PACTOR-4 already. Such auto notch filters are also effective with DSSS and chirp at low information rates as used by the 4 lower sending level of PACTOR-4.

[8] https://ieeexplore.ieee.org/document/1687772

PACTOR-4 has up to 6 concurrent auto notch filters, demonstrating its ability to deal with multiple narrowband interferers simultaneously. This capability is largely enabled or enhanced by using wideband signals with low rate coding such that parts of the received signal spectrum can be removed while still successfully decoding received packets.

	Throughput Comparison VARA v2.2.0/VARA v1.9.1/ARDOP												
Channel													
S/N dB	-12	-10	-8	-6	-4	-2	0	2	4	8	12	16	20
VARA v2.2.0 AWGN 0.0ms 0.0Hz (1)	222	274	275	595	1100	2116	2485	4415	9453	13445	22852	26250	30420
VARA v1.9.1 AWGN 0.0ms 0.0Hz (1)	219	250	253	429	532	1166	2175	3309	4079	11636	14190	20487	27113
ARDOP AWGN 0.0ms 0.0Hz (1)	0	0	360	551	525	1125	1127	1116	2045	3346	4559	8640	8653
VARA v2.2.0 MultiPath Quiet 0.5ms 0.1Hz (2)	0	128	187	269	376	500	1154	1890	3819	7004	11647	14396	18429
VARA v1.9.1 MultiPath Quiet 0.5ms 0.1Hz (2)	0	120	146	214	260	391	682	1529	2506	5941	11024	11698	15656
ARDOP MultiPath Quiet 0.5ms 0.1Hz (2)	0	0	87	198	243	261	266	739	951	1368	1906	3071	3465
VARA v2.2.0 MultiPath Moderate 1.0ms 0.5Hz (3)	0	0	176	224	283	624	987	1523	1888	7434	13677	17618	17090
VARA v1.9.1 MultiPath Moderate 1.0ms 0.5Hz (3)	0	0	134	207	264	442	789	1679	1844	6985	13067	12830	13835
ARDOP MultiPath Moderate 1.0ms 0.5Hz (3)	0	0	0	0	114	175	410	572	627	1350	2604	3365	3699
VARA v2.2.0 MultiPath Disturbed 3.0ms 1.0Hz (4)	0	0	0	194	246	362	583	989	2414	6198	9135	11836	11910
VARA v1.9.1 MultiPath Disturbed 3.0ms 1.0Hz (4)	0	0	0	139	227	241	242	825	2184	6418	10173	11685	12069
ARDOP MultiPath Disturbed 3.0ms 1.0Hz (4)	0	0	0	0	0	0	0	152	220	344	559	800	1822
Notes:	**Channel Conditions based on Mid Latitude in document ITU-R F.1487 May, 2000**												
	1) AWGN (White Gaussian Noise) 3 KHz BW												
	2) MPQ (Multipath Quiet), Delay 0.5ms, Spread Doppler 0.1Hz (Former ITU RF 520 Multipath Good)												
	3) MPM (Multipath Moderate), Delay 1 ms, Spread Doppler 0.5Hz (Former ITU RF 520 Multipath Poor)												
	4) MPD (Multipath disturbed) Delay 3 ms, Spread Doppler 1 Hz												

The measured performance of VARA is shown here against AWGN and certain HF channel models.[9] The modem maintains useful throughput on an AWGN channel for SNR's as low as -12 dB. What is not captured here is the performance with a narrowband interferer. But it may be able to withstand much lower levels of SIR than SNR for narrowband interference, perhaps -20 dB or more. Furthermore, if automatic notch filters are included or added later, even lower levels of SIR should be possible.

The use of notch filters has limited effectiveness with narrowband digital signals. The technique with narrowband digital signals is primarily to use optimized narrowband filters. Furthermore, the desired signals with narrowband operation have limited resistance to spectral distortion caused by narrowband notch filters due to limited BTI. Notch filters have been used for many decades when receiving phone transmissions to eliminate narrowband interference such as carriers or CW. In that case, natural voice has strong inherent redundancy, and so removing small segments of the voice spectrum only hinders intelligibility marginally.

Wideband digital modems with low information bit rates (high BTI plus wideband) make operation with automatic notch filters and suppression of strong narrowband interferers more possible and attractive, but the narrowband signals do not have an effective similar option creating an incompatibility. The lowest information bit rates are associated with SS techniques in VARA as they are with PACTOR-4.

[9] https://digitalradio.groups.io/g/main/attachment/50528/0

There is an argument that high levels of BTI or signals with SS properties are OK for narrowband signals where the intent is clearly to support weak signal communications and the narrow bandwidths minimize spectrum usage. However, even there, JT9 and FT8 only have BTI's in the 8x to 13x range. And the technology has evolved there from JT65A with a very high BTI of about 115x to the more moderate and efficient BTI's of JT9 and FT8. It does not appear that for modes using bandwidths of < 100 Hz that BTI is a concern today (although this may not always be the case).

The situation is different for wideband digital modems where we now see BTI's of >40x for PACTOR-4 and >50x for VARA while occupying channels in the 2.2 to 2.8 KHz range. The combination of high BTI and wide bandwidth is a red flag for compatibility of narrowband and wideband signals and indicates issues beyond basic compatibility problems.

Limiting wideband digital modems to BTI of 6x to 8x would be appropriate to constrain any usage of SS. This would allow the lowest speed mode of PACTOR-4 that does not use SS as detailed in the technical description for PACTOR-4 which is sending level 5 with BTI of 5.4x with margin. It is also consistent with a factor of 3x for 1/3 rate channel coding combined with binary modulation such as BPSK and a factor of 2x to almost 3x for overheads. This constraint would not prevent improving the performance of the modem against noise by adapting the bandwidth to narrow channels as is done by ARDOP and by PACTOR-3 while lowering the information bit rate. It addresses the question of what does "wide bandwidth" mean in the definition of SS. For weak signal modes with very narrow bandwidth < 100 Hz like JT9 and FT-8, there is an argument for higher levels of BTI, and allowing 12x to 16x or twice the BTI for wideband digital modems allows the narrowband modes to reduce the ideal code gap to Shannon's limit from about 0.75 dB to about 0.38 dB. The very narrow bandwidth relaxes the need to constrain SS properties.

PACTOR-4 spread spectrum discussion

While PACTOR-4 sending level 1 sweeps the modulated signal during the course of a packet codeword over a bandwidth of about 10x the bandwidth of the non swept signal (commonly called chirp SS), PACTOR-4 sending levels 2 to 4 used DSSS. The sequence lengths are 16 for levels 2 and 3, and 8 for level 4. Each sequence is a series of complex numbers used to spread the spectrum by factors of 8x or 16x. In fact, the sequences used are ideal or optimal for spectrum spreading. They are as follows:[10]

For spreading factor 16:

```
short scsSpread16[32] =
{
31159,-10139,32319,5401,32217,5976,29448,14370,
32609,-3209,11128,30820,-30546,-11858,-12215,-30405,
32636,2929,-31477,9102,31522,8948,-27518,17789,
32524,-3981,12148,-30432,-32393,-4939,-986,32752
};
```

For spreading factor 8:

```
short scsSpread8[16] =
{
```

[10] https://www.p4dragon.com/download/PACTOR-4%20Protocol.pdf

```
32767, 0, 30273, 12539, 0, 32767, -30273, -12539,
32767, 0, -30273, -12539, 0, 32767, 30273, 12539
};
```

An examination of these sequences reveals that all complex numbers have identical amplitudes. This is done to obtain a flat energy response over time, and to avoid increasing peak to average power ratios by the DSSS process, so that transmitter power can be maximized on the average under peak power constraints. Furthermore, if the spectrum is computed for each sequence, it is found that these sequences are also flat in the frequency domain. Each frequency bin has equal amplitude. Such sequences are special and are known in the art for jointly achieving flat time and frequency responses.

These sequences spread the spectrum of each individual modulation symbol uniformly over the expanded bandwidth with spreading factors of 8x or 16x. This optimizes resistance to unknown narrowband interferers. Regardless of where a narrowband interferer may appear in the wider SS signal, once the narrowband interferer is suppressed with an auto notch filter, the remaining desired signal energy is the same (ignoring effects at the edge of the channel).

Overall, the DSSS sequences used for PACTOR-4 sending levels 2 to 4 provide high performance to resist narrowband interference and to maximize SS gains. This is not a coincidence of course. It is designed well.

Ideas on why a modulation and coding format should not be considered spread spectrum

There are a large number of ideas posited on why some modulation and coding formats that meet the FCC's definition of spread spectrum should not be so considered. Here is a partial list:

1) The transmitter's VFO is not manipulated during transmissions
2) The signal is contained fully within the 2.8 KHz audio passband of the radio
3) The bandwidth of the signal is the same in SS modes compared to non-SS modes
4) The same TX filter is used for SS and non-SS modes
5) There is no hopping of carrier frequency
6) The same spreading code is repeated for each info data symbol and a long PN sequence is not used
7) The emissions designator must end in XX to be SS
8) RTTY spreads the signal also
9) ROS simply uses MFSK and should not be considered FHSS
10) FT-8 employs FHSS, because a responding DX station during split frequency operation may respond on the frequency on which it is being called

In 2012, the FCC granted a STA for HF SS testing. The bandwidth was to be limited to 2.5 KHz, and the emissions designator was 2K50J2D.[11] The FCC recognized that SS within a 2.5 KHz bandwidth, no doubt using SSB audio coupling to the radio equipment involved, should be properly classified as SS depending on the characteristics of the emissions. This STA alone is sufficient to lay aside many incorrect ideas about why some modulation and coding formats should not be considered SS (they are SS actually considering BTI).

[11] https://apps.fcc.gov/els/GetAtt.html?id=122008&x=.

The emissions designator idea is addressed. The bandwidth is only 2.5 KHz (about) idea is addressed. The VFO is not manipulated and there is no frequency hopping ideas are addressed by this STA. This STA would not have been needed if emissions in different modes using the same TX filter and emissions bandwidth with some modes using SS and some modes not using SS, means that SS is not used. The tests would only have needed to transmit at least one packet during a session without SS to meet FCC requirements (if such an interpretation is allowed). The idea that FT-8 employs FHSS when changing frequency to send a transmission is otherwise known to radio amateurs as a QSY or switching of the sending frequency to send a message. It is not SS since there is no spreading of information for the duration of the message.

When the FCC RM-11325 definition: “Spread spectrum techniques are emissions that use bandwidth-expansion modulation techniques to intentionally spread the information transmitted over a wide bandwidth.” is applied, these ideas are not pertinent.

Wideband HF Technology and Interference Issues

Modern amateur radio equipment already is often built to support 5 to 10 KHz SSB channels and perhaps as wide as 20 KHz, and even wider channels could be easily added. ESSB (Enhanced Single Side-Band) operations have helped to stimulate these capabilities along with SDR.[12] Audio interfaces for PC’s are normally 20 KHz wide. Hence, the hardware to deploy up to 20 KHz wide HF modems is readily available and sometimes already in use by amateur radio operators.

Recent years have seen a significant interest in wideband HF modem technology for commercial and military usage. Of course the licensees have dedicated or generally well managed shared spectrum for usage. These developments show the viability of HF modems much wider than a few KHz. MIL-STD-188-110D supports HF data rates up to 240 kbps using bandwidths up to 48 KHz.[13] TrellisWare received at STA for testing digital HF modems with a BW of 30 KHz in 2014.[14] In 2016, Mitre Corporation filed exhibits for HF wideband digital modem experiments using bandwidths up to 400 KHz in the 6 to 11 MHz HF spectrum.[15]

Without bandwidth constraints on HF digital modems for amateur radio operations, deployment of digital modems up to 10 KHz in width is likely to happen quite rapidly based on existing hardware and expansion to 20 KHz may not be far behind. Since existing HF digital modem systems for radio amateurs are based on SSB audio with bandwidths of 2 to 3 KHz, initial operations up to 10 KHz may use carrier aggregation of 2 to 4 legacy channels. A primary carrier operates with a legacy 2 to 3 KHz channel and is used for access and capability negotiations. If both ends of a link support carrier aggregation, then the link automatically transitions to wider bandwidth 10 to 20 KHz operation using multiple carriers, otherwise a legacy 2 to 3 KHz carrier may be used. Of course, new and incompatible modems are also likely to develop, but carrier aggregation allows existing HF networks to easily add wider bandwidth capabilities for users that upgrade while maintaining compatibility with existing users. Carrier aggregation also can be readily implemented using existing modems implemented with multiple instantiations (perhaps entirely in SW) and some minor combining/filtering functions.

[12] http://www.nu9n.com/essb_ready_rigs.html
[13] http://tracebase.nmsu.edu/hf/MIL-STD-188-110D.pdf
[14] https://apps.fcc.gov/els/GetAtt.html?id=154291&x=.
[15] https://fcc.report/ELS/The-MITRE-Corporation/0660-EX-ST-2016/176207

The ready availability of amateur radio equipment capable of supporting HF digital modems up to 10 KHz and possibly 20 KHz in bandwidth combined with the SS features now appearing in HF digital modems with BTI rates exceeding 40x presents major issues for spectrum sharing with narrowband emissions. When the well developed and also implemented narrowband suppression (auto notch) technologies are combined with the possibility of 10 to 20 KHz wideband digital HF modems proliferating with SS properties, the risk of significant interference issues is strong. Limiting the bandwidth of HF digital emissions in the HF amateur radio bands is critical to manage interference.

Conclusion

I found that the definition of spread spectrum from FCC RM-11325 ("Spread spectrum techniques are emissions that use bandwidth-expansion modulation techniques to intentionally spread the information transmitted over a wide bandwidth.") continues to work well to determine the usage of spread spectrum for any amateur radio emissions, and that PACTOR-4 sending levels 1 to 4 and VARA levels 1 to 4 violate this limitation. Specifically these emissions use transmission Bandwidth To Information rate ratios (BTI's) that are over 5x to 10x and are actually described with SS language for PACTOR-4. Sending level 1 of PACTOR-4 exceeds a BTI of 40x, and VARA level 1 exceeds a BTI of 50x. Large BTI's are not found in systems like PSK31, Clover, JT9, FT-8, legacy RTTY,…. It must be noted that Section 97.307(a) of the Commission's Rules "No amateur station transmission shall occupy more bandwidth than necessary for the information rate and emission type being transmitted, in accordance with good amateur practice." appears to be in conflict with PACTOR-4 and VARA sending levels 1 to 4 emissions, but nevertheless these emissions are using bandwidth to information ratios that are very large.

I found that PACTOR-4 sending levels 2 to 4 use ideal sequences to spread the spectrum 16x for sending levels 2 & 3 and 8x for sending level 4 compared to the modulation symbol rate. These sequences spread the spectrum of each individual modulation symbol by 16x or 8x. The spectrum of these sequences is ideally flat which maximizes the spread (gives a uniform spread) for each individual modulation symbol. These sequences have constant amplitude in time which maximizes transmit average power limited by some peak transmitter power. These findings further clarify and confirm the usage of spread spectrum in PACTOR-4.

I found that VARA documentation in the public domain is very limited and does not meet FCC requirements. The usage of Forward Error Correction coding is only documented as: "Turbo codification is used for the Forward Error Correction with different redundancy levels to give 11 speed Levels with different Net Data Rates." This is far short of documenting this important component of the modem. There are similar gaps throughout the key components of the modem. Furthermore, VARA uses SS technology based on an analysis of BTI which exceeds 50x.

The usage of SS technology in several wideband modems combined with automatic notch filters or OFDM to suppress narrowband emissions results in strong incompatibility in sharing spectrum. The technical literature shows examples of such systems suppressing narrowband interference by as much as 30 dB. These factors amplify issues of incompatibility that are significant even without the use of SS techniques.

To define the boundary of SS, limiting the BTI (bandwidth to information ratio) of wideband digital HF modems to less than 6x to 8x is proposed, and limiting the BTI for very narrowband signals of < 100 Hz bandwidth used for weak signal communications to 12x to 16x is proposed. RTTY should be excluded from this constraint as a legacy mode which is otherwise constrained already. These proposed rules do not impact rules for SS, but provide a boundary to disallow SS in HF modems. VARA has only recently been brought into service and PACTOR-4 is not yet allowed in the USA. They appear to be the first to introduce SS with significant spectral spreading in wideband digital modems in the USA. Thus it is timely to address this issue which is closely related also to the issue of wideband and narrowband technologies compatibility in sharing spectrum and to HF band segments where ACDS and wideband digital modems are allowed. Wideband digital modems should be limited to 2.8 KHz also as a further constraint on usage of SS techniques and due to the limited bandwidth available on HF bands. The following language would address the boundary of SS:

§ 97.309 (a) ….. (5) Except for RTTY, the bandwidth to information ratio of data emissions in HF, MF and LF bands shall not exceed a ratio of 8 to 1, and for emissions less than 100 Hz in bandwidth, the bandwidth to information ratio shall not exceed 16 to 1.

It was found that equipment is readily available and already is use by radio amateurs to support HF digital modem emissions up to 10 KHz to 20 KHz in bandwidth. Such emissions are likely to happen rapidly with a ruling allowing unconstrained baud rate and unconstrained bandwidth except for band segment limits. Significant interference problems are then likely. A bandwidth constraint on digital emissions is important.

If wideband HF digital modems are limited in BTI to 8x, limited in bandwidth to 2.8 KHz, limited to the existing or moderately modified ACDS band segments, and transparency and documentation is addressed, then the removal of the 300 baud data limitation is appropriate in those band segments. Wideband digital signals in the HF amateur bands and ACDS must be carefully constrained to appropriate segments of the bands and constrained in bandwidth. If SS techniques (high BTI) are allowed with wideband digital HF modems in the amateur radio bands, this places special considerations on spectrum compatibility with narrowband signals.

I respectfully urge the Commission to adapt RM-11831 and to reject WT Docket No. 16-239.

Respectfully submitted,

Nelson Sollenberger, KA2C